

WHAT IS CLAIMED IS:

1. A process for detection of cardiac movement comprising:
 - a. acquiring a series of successive images I_n of the region of a heart;
 - b. analyzing at least some of the images thus acquired to identify a heart movement; and
 - c. determining the cardiac cycle starting from this movement.

2. The process according to claim 1 comprising:
 - a. acquisition of a series of successive images I_n of the region of the heart;
 - b. determination of a cranio-caudal axis of the heart;
 - c. for each image I_n , calculation of the series of images of a set of attenuation coefficients of points on the image representing vessels in the region of the heart along lines perpendicular to the cranio-caudal axis of the heart;
 - d. calculation of the integral overrun $k_{n,n+2}$ between two successive images I_n and I_{n+1} of the series of images starting from the set of attenuation coefficients calculated for each of the two successive images; and
 - e. determination of the cardiac cycle starting from all previously calculated integral displacements.

3. The process according to claim 2 wherein step b comprises:
 - b1. for each image I_n in the series of images, calculation of an associated thresholded image IS_n , only keeping vessels in the heart region, and
 - b2. determine all attenuation coefficients for points on the image starting from thresholded images along lines perpendicular to the axis of the heart.

4. The process according to claim 3 wherein the step to calculate the thresholded image IS_n comprises:
 - b1i. determination of at least one dimension, particularly a diameter, of vessels in the heart region to be kept;

blii. calculation of a closing image starting from the maximum dimension of vessels in the heart region to be kept;

bliii. calculation of an intermediate image by subtracting the closing image from the initial image; and

bliv. calculation of the thresholded image by application of an appropriate thresholding on the intermediate image.

5. Process according to claim 4 wherein the thresholding is applied such that it keeps only about 15% of the pixels in the intermediate image.

6. The process according to claim 2 wherein the set of attenuation coefficients of points on image I_n along line i is modeled by a linear integral $f_{ln}(i)$ of these attenuation coefficients along this line.

7. The process according to claim 3 wherein the set of attenuation coefficients of points on image I_n along line i is modeled by a linear integral $f_{ln}(i)$ of these attenuation coefficients along this line.

8. The process according to claim 4 wherein the set of attenuation coefficients of points on image I_n along line i is modeled by a linear integral $f_{ln}(i)$ of these attenuation coefficients along this line.

9. The process according to claim 5 wherein the set of attenuation coefficients of points on image I_n along line i is modeled by a linear integral $f_{ln}(i)$ of these attenuation coefficients along this line.

10. The process according to claim 6 wherein the linear integral is expressed

by a formula for line i , $f_{ln}(i) = \sum_{j=0}^{\text{Nb. of columns}} \frac{I_n(i,j)}{I_{0n}(i,j)}$ where $I_n(i,j) = R_{00}e^{-\int_{C(V)} \mu(x) dx - \int_{C(F)} \mu(x) dx}$ and $I_{0n}(i,j) = R_{00}e^{-\int_{C(F)} \mu(x) dx}$,

where:

R_{00} is the initial intensity of radiation;

$C(M)$ is the path between a radiation source and a point M on an image I_n with coordinates (i,j) in pixels on the image;

μ is the local attenuation coefficient along path $C(M)$ that depends on the nature of the tissues crossed and the wavelength of the radiation used;

V represents all points on image I_n belonging to the projected vessels through which the radiation pass; and

F represents all points belonging to other tissues projected onto image I_n .

11. The process according to claim 7 wherein the linear integral is expressed by a formula for line i , $f_{In}(i) = \sum_{j=0}^{\text{Nb. of columns}} \ln \frac{I_n(i,j)}{I_{0n}(i,j)}$ where $I_n(i,j) = R_{00}e^{-\int_{C(V)} \mu(x)dx - \int_{C(F)} \mu(x)dx}$ and

$$I_{0n}(i,j) = R_{00}e^{-\int_{C(F)} \mu(x)dx},$$

where:

R_{00} is the initial intensity of radiation;

$C(M)$ is the path between a radiation source and a point M on an image I_n with coordinates (i,j) in pixels on the image;

μ is the local attenuation coefficient along path $C(M)$ that depends on the nature of the tissues crossed and the wavelength of the radiation used;

V represents all points on image I_n belonging to the projected vessels through which the radiation pass; and

F represents all points belonging to other tissues projected onto image I_n .

12. The process according to claim 8 wherein the linear integral is expressed by a formula for line i , $f_{In}(i) = \sum_{j=0}^{\text{Nb. of columns}} \ln \frac{I_n(i,j)}{I_{0n}(i,j)}$ where $I_n(i,j) = R_{00}e^{-\int_{C(V)} \mu(x)dx - \int_{C(F)} \mu(x)dx}$ and

$$I_{0n}(i,j) = R_{00}e^{-\int_{C(F)} \mu(x)dx},$$

where:

R_{00} is the initial intensity of radiation;

$C(M)$ is the path between a radiation source and a point M on an image I_n with coordinates (i,j) in pixels on the image;

μ is the local attenuation coefficient along path $C(M)$ that depends on the nature of the tissues crossed and the wavelength of the radiation used;

V represents all points on image I_n belonging to the projected vessels through which the radiation pass; and

F represents all points belonging to other tissues projected onto image I_n .

13. The process according to claim 9 wherein the linear integral is expressed by a formula for line i , $f_{In}(i) = \sum_{j=0}^{\text{Nb. of columns}} \ln \frac{I_n(i,j)}{I_{0n}(i,j)}$ where $I_n(i,j) = R_{00} e^{-\int_{C(V)} \mu(x) dx - \int_{C(F)} \mu(x) dx}$ and

$$I_{0n}(i,j) = R_{00} e^{-\int_{C(F)} \mu(x) dx},$$

where:

R_{00} is the initial intensity of radiation;

$C(M)$ is the path between a radiation source and a point M on an image I_n with coordinates (i,j) in pixels on the image;

μ is the local attenuation coefficient along path $C(M)$ that depends on the nature of the tissues crossed and the wavelength of the radiation used;

V represents all points on image I_n belonging to the projected vessels through which the radiation pass; and

F represents all points belonging to other tissues projected onto image I_n .

14. The process according to claims 6 wherein the integral displacement $k_{n,n+1}$ between two successive images I_n and I_{n+1} is calculated starting from all linear integrals associated with each successive image.

15. The process according to claims 7 wherein the integral displacement $k_{n,n+1}$ between two successive images I_n and I_{n+1} is calculated starting from all linear integrals associated with each successive image.

16. The process according to claims 8 wherein the integral displacement $k_{n,n+1}$ between two successive images I_n and I_{n+1} is calculated starting from all linear integrals associated with each successive image.

17. The process according to claims 9 wherein the integral displacement $k_{n,n+1}$ between two successive images I_n and I_{n+1} is calculated starting from all linear integrals associated with each successive image.

18. The process according to claims 10 wherein the integral displacement $k_{n,n+1}$ between two successive images I_n and I_{n+1} is calculated starting from all linear integrals associated with each successive image.

19. The process according to claim 14 wherein the integral displacement is the value of $k_{n,n+1}$ that minimizes an $F_{n,n+1}(k_{n,n+1}) = \sum_i |f_{I_n}(i) - f_{I_{n+1}}(i - k_{n,n+1})|$ type cost function.

20. The process according to claim 7 wherein the integral displacement is the value of $k_{n,n+1}$ that minimizes an $F_{n,n+1}(k_{n,n+1}) = \sum_i |f_{I_n}(i) - f_{I_{n+1}}(i - k_{n,n+1})|$ type cost function.

21. The process according to claim 8 wherein the integral displacement is the value of $k_{n,n+1}$ that minimizes an $F_{n,n+1}(k_{n,n+1}) = \sum_i |f_{I_n}(i) - f_{I_{n+1}}(i - k_{n,n+1})|$ type cost function.

22. The process according to claim 9 wherein the integral displacement is the value of $k_{n,n+1}$ that minimizes an $F_{n,n+1}(k_{n,n+1}) = \sum_i |f_{I_n}(i) - f_{I_{n+1}}(i - k_{n,n+1})|$ type cost function.

23. The process according to claim 10 wherein the integral displacement is the value of $k_{n,n+1}$ that minimizes an $F_{n,n+1}(k_{n,n+1}) = \sum_i |f_{I_n}(i) - f_{I_{n-1}}(i - k_{n,n+1})|$ type cost function.

24. The process according to claim 1 comprising:

f. choose a subset of synchronous images in the heart cycle from the series of images, starting from the previously determined cardiac cycle.

25. The process according to claim 10 comprising:

g. determine an integral displacement due to breathing of a patient between synchronous images, the determination being done in the same way as in step c.

26. A radiography apparatus comprising:

means for providing a source of radiation;

means for recording images facing the source;

means for support placed between the source and the means for recording images on which there is a patient for whom a region of a heart is to be imaged,

wherein the radiography apparatus comprises means for implementing the process of claim 1.

27. A computer program comprising computer readable program code means, the computer readable program code means for causing a computer to provide:

a. acquiring a series of successive images I_n of the region of a heart;

b. analyzing at least some of the images thus acquired to identify a heart movement; and

c. determining the cardiac cycle starting from this movement.

28. A computer program product comprising a computer useable medium having computer readable program code means embodied in the medium, the computer program product comprising;

a. computer readable program code means embodied in the medium for causing a computer to provide acquiring a series of successive images I_n of the region of a heart;

b. computer readable program code means embodied in the medium for causing a computer to provide analyzing at least some of the images thus acquired to identify a heart movement; and

c. computer readable program code means embodied in the medium for causing a computer to provide determining the cardiac cycle starting from this movement.

29. An article of manufacture for use with a computer system, the article of manufacture comprising a computer readable medium having computer readable program code means embodied in the medium, the program code means comprising:

a. computer readable program code means embodied in the medium for causing a computer to provide acquiring a series of successive images I_n of the region of a heart;

b. computer readable program code means embodied in the medium for causing a computer to provide analyzing at least some of the images thus acquired to identify a heart movement; and

c. computer readable program code means embodied in the medium for causing a computer to provide determining the cardiac cycle starting from this movement.